Final Technical Report for NASA Grant 5-1698

CNO Processing in Massive Algol Binaries

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The Pennsylvania State University
University Park, PA 16802

Richard A. Wade, Principal Investigator
Department of Astronomy & Astrophysics
525 Davey Lab
Pennsylvania State University
University Park PA 16802

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This program, undertaken in collaboration with Dr. Ronald S. Polidan (GSFC), used ultraviolet observations by the IUE Observatory along with other tools to search for abundance anomalies indicative of CNO processing in the secondary (mass–donating) stars of six interacting binary systems. Related IUE-based activities were also undertaken under this grant.

Two Supplements to the grant were awarded. Supplement No. 1 was in connection with the NASA Grant Supplements for Education program, for a workshop for elementary school science teachers. The two sessions of the workshop were held October 24 and November 14, 1992. Christopher J. Foster was principle coordinator, and Regis Huschak (Director of the Neil Armstrong Planetarium of the Altoona, PA, School District) was principle activities leader. Eighteen school teachers from central Pennsylvania, grades 1-7, participated in the workshop, for which they received one unit of in-service training credit from their Intermediate Unit. Supplement No. 2 was awarded for additional IUE observations of the Algol stars V342 Aql and TU Mon.

Personnel at Penn State supported in part by the grant were the PI (Wade, throughout) and undergraduates Jeff Matus (Summer 1994) and Kevin McGouldrick (Fall 1996 and Spring 1997). Dr. Alan Welty also collaborated on optical observations of V342 Aql.

Observations of all six candidate stars were made with IUE, and attention was narrowed to TU Mon in particular, for which further IUE observations were made using Director's discretionary time. Observations of TU Mon were also carried out with the Voyager UV spectrometers, and optical spectroscopy was obtained on several occasions at Penn State's Black Moshannon Observatory. Photometric data on TU Mon were acquired by Dr. Paul Etzel at Mt. Laguna Observatory (MLO). Study of TU Mon continues under the guidance of Polidan.

McGouldrick was employed part-time during the Fall academic semester to assist in accessing the IUE Archive, and to correlate data on some cataclysmic variables and related objects that were observed with both IUE and the Voyager Far Ultraviolet Spectrometers. Approximately 21 relevant binary systems were observed with the Voyager UVS over the past decade, and a paper is being prepared for eventual publication that will serve as an index to the UVS data archive on these stars, providing observation dates, mean count rates in far and extreme UV bands, and a discussion of the relevant literature concerning the far UV behavior (including correlative IUE information from the archive and the literature).

Much of the activity under the grant was in connection with V342 Aquilae, a 3.39 day Algol system thought to be in a state of rapid mass transfer. The goal was to combine optical and ultraviolet data to arrive at a robust, informative interpretation of this unique binary system. The bulk of the analysis work was undertaken by Ms. Colleen Hartman of Catholic University, as part of her Ph.D. dissertation. Additional IUE spectra were obtained under Supplement No. 2. Optical echelle spectroscopy of V342 Aql was acquired by Welty at the Kitt Peak National Observatory 84-inch telescope, using the Penn State Fiber Optic Echelle (FOE) system. Etzel acquired photometry and near-infrared spectra at MLO. Wade computed synthetic spectra of hot stars, using I. Hubeny's SYNSPEC code, to aid in the

search for photospheric features due to the primary star in the observed spectra.

Complete orbital phase coverage of V342 Aql was obtained spectroscopically and photometrically. Analysis of the eclipsing binary at visible wavelengths showed that the system is heavily enshrouded with gas. Nevertheless, the stellar components were identified as a B7±2 V primary star and an early G III secondary star with a mass ratio of 0.4±0.1. The effective temperatures are 10,500±1,500 K and 5,000±1,000 K. The semi-major amplitude of the primary star radial velocity curve was found to be 90±5 km sec^{-1} from measurements of Si II, Hγ, He I, Mg II, and Hδ. In the ultraviolet, emission lines from ionized species, which cannot be photoionized by the star, dominate the spectra at totality. The strongest lines are C IV, Mg II, Si IV, and C II, while N V is much weaker. There is a striking similarity to the interacting binary TT Hydrae (B9.5 V+ K0 III), which was also a target of this program.

The stellar parameters and orbital geometry of the V342 Aql system are as follows: masses 3.2±0.2 and 1.3±0.5 $M_\odot$, radii 2.5 and 4.7 $R_\odot$, Roche lobe radii 7.2±1.2 $R_\odot$ and 4.7±0.8 $R_\odot$, respectively, separation 15.7 $R_\odot$, and distance to the system 350±20 pc. The mass stream directly hits the gainer and does not form a disk. The ultraviolet spectra outside totality show pronounced Fe II absorption lines arising from ground and metastable levels, indicating an extensive circumstellar gas envelope around the primary. Comparison of synthetic spectra containing the metastable Fe II lines to the observed ultraviolet spectra indicates a gas temperature of $\approx 8,000$ K, and, assuming solar abundances, a hydrogen column density of 10^{24} cm^{-2}. The variation in the absorption spectrum with phase can be explained entirely as due to variation in the velocity field of the gas.

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